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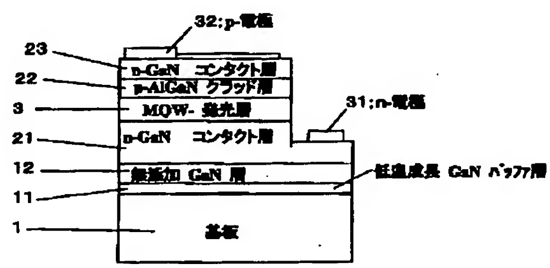
(54)【発明の名称】　多波長発光素子

(57)【要約】

【課題】　単一の発光層から複数の波長の光を発し、しかも一組のｐ型及びｎ型電極に電流を注入するだけで多色発光する、特に白色発光する発光素子を提供すること。

【解決手段】　素子構造は、サファイアＣ面基板１、低温成長されたＧａＮバッファ層１１、無添加のＧａＮ層１２、Ｓｉ添加のｎ-ＧａＮコンタクト層２１、複数の井戸層を有する多重量子井戸構造（ＭＱＷ）の発光層３、Ｍｇ添加のｐ-ＡｌＧａＮクラッド層２２、Ｍｇ添加のｐ-ＧａＮコンタクト層２３からなる。上記発光層３は、そこから発せられる光が、発光スペクトル中に少なくとも２つ以上のピークを含むような多層構造、例えば井戸層のバンドギャップを異ならせたグループを複数設けることで多波長発光が可能とされている。



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【特許請求の範囲】

【請求項１】　ｎ型半導体層と、ｐ型半導体層と、多層構造からなる発光層を備える発光素子において、
発光スペクトル中に少なくとも２つ以上のピークを含む光を発する多層構造を発光層内に有することを特徴とする多波長発光素子。

【請求項２】　発光層が複数の井戸層を有する多重量子井戸構造からなることを特徴とする請求項１記載の多波長発光素子。

【請求項３】　バンドギャップ、井戸層幅、ドーピング量又は種類、及びピエゾ電界強度のいずれか一種又は二種以上を異ならせることで発光波長を異ならせた、少なくとも２つ以上の量子井戸層を、多重量子井戸構造中に配置したことを特徴とする請求項２記載の多波長発光素子。

【請求項４】　発光波長が５２０ｎｍ未満の井戸層と５２０ｎｍ以上の井戸層をそれぞれ少なくとも一つずつ有する多重量子井戸構造を発光層に有することを特徴とする請求項２記載の多波長発光素子。

【請求項５】　発光波長が５２０ｎｍ未満の井戸層のグループをＡ、５２０ｎｍ以上の井戸層のグループをＢとして、正孔を供給する側にグループＡに属する井戸層を配したことを特徴とする請求項４記載の多波長発光素子。

【請求項６】　発光波長が５２０ｎｍ未満の井戸層のグループをＡ、５２０ｎｍ以上の井戸層のグループをＢとして、電子を供給する側にグループＡに属する井戸層を配した事を特徴とする請求項４記載の多波長発光素子。

【請求項７】　発光波長が５００ｎｍ未満の井戸層と、発光波長が５００ｎｍ以上で５５０ｎｍ未満の井戸層と、発光波長が５５０ｎｍ以上の井戸層をそれぞれ一つ以上有する多重量子井戸構造を発光層に有する事を特徴とする請求項２記載の多波長発光素子。

【請求項８】　発光波長が５００ｎｍ未満の井戸層のグループをＡ、発光波長が５００ｎｍ以上で５５０ｎｍ未満の井戸層のグループをＢ、発光波長が５５０ｎｍ以上の井戸層のグループをＣとして、正孔を供給する側にグループＡを、電子を供給する側にグループＣを、これにの中間にグループＢを配したことを特徴とする請求項７記載の多波長発光素子。

【請求項９】　発光波長が５００ｎｍ未満の井戸層のグループをＡ、発光波長が５００ｎｍ以上で５５０ｎｍ未満の井戸層のグループをＢ、発光波長が５５０ｎｍ以上の井戸層のグループをＣとして、電子を供給する側にグループＡを、正孔を供給する側にグループＣを、これにの中間にグループＢを配したことを特徴とする請求項７記載の多波長発光素子。

【請求項１０】　井戸層のバンドギャップを、正孔を供給する側から電子を供給する側に向けて小さくなるように構成したことを特徴とする請求項４又は請求項７記載の多波長発光素子。

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【請求項１１】　障壁層に隣接する井戸層のバンドギャップの大きい方をＥＷＬ［ｅＶ］とし、該障壁層のバンドギャップをＥＢ［ｅＶ］とした時、ＥＢ＜ＥＷＬ＋０．８［ｅＶ］とすることを特徴とする請求項４又は７記載の多波長発光素子。

【請求項１２】　短波長の光を発する井戸層に隣接する障壁層の幅を、長波長の光を発する井戸層に隣接する障壁層に比べて厚くすることを特徴とする請求項４又は７記載の多波長発光素子。

【発明の詳細な説明】

【０００１】

【発明が属する技術分野】本発明は、化合物半導体素子、特に発光素子に関するものである。

【０００２】

【従来の技術】青色ＬＥＤと該ＬＥＤから発する青色光で励起され黄色の蛍光を発する蛍光体との組み合わせで白色発光するＬＥＤが開発され、実用化されている。この様なＬＥＤ（固体発光素子）を使った白色光源は、次世代の新規な照明用の光源として期待されている。該白色光源は、他に紫外ＬＥＤと紫外光を多波長に変換する蛍光体との組み合わせや、さらに青色、緑色、赤色などの複数色の可視ＬＥＤを組み合わせる方法等によっても実現されている。

【０００３】しかし、紫外ＬＥＤを使う方法は、高エネルギーのキャリヤを注入し発光した紫外線を低エネルギーの可視光に変換するために、波長変換によるエネルギー損失が大きく、エネルギー利用効率に限界があると考えられる。この問題は、青色ＬＥＤと蛍光体と組み合わせて使用する場合も同様に存在する。一方、複数色の可視ＬＥＤを使い補色関係で白色光を得る方法は、波長変換が無いためにエネルギー利用効率は優れるといった利点がある。しかし、多点光源となり光の混合が悪い、駆動電圧が発光波長毎に異なるので駆動回路が複雑になる、劣化モードが発光波長毎に異なるために、経時的に色調が変化するなどの問題点を多く有している。

【０００４】

【発明が解決しようとする課題】上記の問題点を鑑み、本発明者らは、蛍光体などを使った波長変換工程を含まない、直接電光変換されるエネルギー利用効率の高い多波長発光素子を開発することを試み、本発明を完成した。

【０００５】ところで、１つのチップから多波長を発光するＬＥＤは種々考案され、また開発されてきた。しかし、その大半は発光波長毎に異なる発光層として積層され、各発光層の両側にｎ型半導体層及びｐ型半導体層を配した構造になっている。そのため、各発光層に少なくとも１つの外部取出し電極が必要となり、駆動回路の複雑さ、劣化モードの違いによる色調の変化などの問題は何ら解決されていない。

【０００６】本発明は、上記の従来のコンセプトと異なり、単一の発光層から複数の波長の光を発し、しかも一組のｐ型及びｎ型電極に電流を注入するだけで多色発光する新しいコンセプトに基づく発光素子を提供することを目的とする。単一発光層故に劣化モードの違いに起因した色調の変化も無く、波長混合性にも優れ、駆動回路も単純化された扱い易い白色光源を提供するものである。

【０００７】

【課題を解決するための手段】従来の白色光源には、①紫外線ＬＥＤ或いは青色ＬＥＤと蛍光体の組み合わせ、②複数色の可視ＬＥＤの組み合わせ、③従来の多色発光チップを使った方式、の上記問題点を解決するため、単一の発光層から多色の発光が得られる新しい素子構造を開発した。即ち、本発明の多波長発光素子は、ｎ型半導体層と、ｐ型半導体層と、多層構造からなる発光層を備える発光素子において、発光スペクトル中に少なくとも２つ以上のピークを含む光を発する多層構造を発光層内に有することを特徴とするものである。

【０００８】上記発光層は多重量子井戸構造からなることが好ましく、この場合、バンドギャップ、井戸層幅、ドーピング量又は種類、及びピエゾ電界強度のいずれか一種又は二種以上を異ならせることで発光波長を異ならせた、少なくとも２つ以上の量子井戸層を、多重量子井戸構造中に配置することで多波長化を達成できる。

【０００９】

【作用】一般に発光素子中の発光層として使われる多重量子井戸構造は、通常同じ特性（バンドギャップ等）を有する井戸層を、発光効率を上げるために複数配した構造をしている。即ち、障壁層（Ｂａｒｒｉｅｒ層）／井戸層（Ｗｅｌｌ層）／障壁層／井戸層／・・／障壁層なる多重量子井戸層において、井戸層は同じ構造（組成、バンドギャップ、井戸幅）であり、障壁層も幅に関しては変調をかける場合もあるが、組成（バンドギャップ）は両端を除いて同一の場合が多い。

【００１０】これに対し本発明者らの開発した素子構造は、一つの発光層中の多重量子井戸構造を形成する井戸層及び／又は障壁層の組成（バンドギャップ）や幅を変調する事を特長にしており、単一の発光層から高効率の多色発光、特に白色発光が得られる。すなわち、通常の発光素子構造において一つの発光層として認識されている層中に、互いに性質の異なる井戸層と障壁層とのペアを二種以上混在させることで各ペア毎に異なる波長の発光を得ることができるようにし、もって発光スペクトル中に少なくとも２つ以上の発光ピークを有する発光素子を構成するものである。かかる構成によれば、蛍光体を用いない直接電光変換方式であるのでエネルギー利用効率は良く、また発光層は見かけ上は一層であるので素子構造の複雑化等を伴うことはない。

【００１１】

【発明の実施の態様】以下図面に基づいて、本発明の実施態様につき説明する。図１は本発明の化合物半導体発光素子の一実施例を示しており、下側よりサファイアＣ面基板１、低温成長されたＧａＮバッファ層１１、無添加のＧａＮ層１２、Ｓｉ添加のｎ-ＧａＮコンタクト層２１、複数の井戸層を有する多重量子井戸構造（ＭＱＷ）の発光層３、Ｍｇ添加のｐ-ＡｌＧａＮクラッド層２２、Ｍｇ添加のｐ-ＧａＮコンタクト層２３からなり、ｎ-ＧａＮコンタクト層２１の露出部にはｎ電極３１が、ｐ-ＧａＮコンタクト層２３の表面にはｐ電極３２がそれぞれ設けられている。本発明においては、上記発光層３から発せられる光が、発光スペクトル中に少なくとも２つ以上のピークを含むような多層構造とされている点に特徴がある。なお、ここで言うピークとは、急峻なピークに限らずブロードなピークをも含むものとし、またブロードな２つのピークが重なって見かけ上１つのピークを形成しているような場合も包含する。

【００１２】上述の通り、発光層３は発光スペクトル中に少なくとも２つ以上のピークを含むような多層構造とされる。この多層構造は、代表的には多重量子井戸構造とされる。該多重量子井戸構造は、井戸層とバリア層を１つのペアとし、このようなペアが複数段積重されている構造である。そして本発明では、前記積重されたペアを発生させたいピーク光の数に応じて区分けして、即ち３波長発光素子ならば３つにグループ化して、そのグループ毎に例えばバンドギャップ、井戸層幅、ドーピング量又は種類、及びピエゾ電界強度のパラメータいずれか一種又は二種以上を異ならせることで複数の発光波長の光を発生させるようにするものである。

【００１３】図２は上記したパラメータのうち、区画毎にバンドギャップを異ならせた場合の例であって、３波長発光素子とした場合の発光層３のバンド構造を模式的に示した図である。発光層３は井戸層のバンドギャップを異ならせることで３つに区画した、第１グループ３ａ、第２グループ３ｂ、第３グループ３ｃからなっており、これらは全て無添加のＩｎＧａＮで構成している。詳細には、ｎ-ＧａＮコンタクト層２１側より、約６００ｎｍの朱色を発する３層の井戸層３１ａとその間のバリア層３２ａからなる第１グループ３ａ、約５３５ｎｍの緑色を発する１層の井戸層３１ｂ及び隣接するバリア層３２ｂからなる第２グループ３ｂ、及び約４７０ｎｍの青色を発する１層の井戸層３１ｃ及び隣接するバリア層３２ｃからなる第３グループ３ｃが配置されている。

【００１４】本材料系の場合、活性層内に注入された正孔の平均自由工程が数十ｎｍと言われており、正孔を如何に効率良く多重量子井戸層内に注入・拡散させるか、またバランスの取れた多色発光を得るためには如何なる層構造にするべきが課題となる。図２の例では、電子は均一に拡散していると考えて良く、発光波長のバランスは正孔の分布によってほぼ決定される。従って、正孔を

供給する側であるｐ-ＡｌＧａＮクラッド層２２側に青色発光をなす第３グループ３ｃを配しているが、正孔の密度も高いために井戸層３１ｃは単層とした。次に中間位置に緑色発光をなす第２グループ３ｂを配しているが、正孔密度は若干低下するものの緑色の視感度が高いためにこれも井戸層３１ｂは単層で十分である。最後にｎ-ＧａＮコンタクト層２１側に朱色発光をなす第１グループを配したが、正孔密度は低下し視感度も低下するので井戸層３１ａを３層入れて構成している。

【００１５】また、正孔がより拡散し易くするためにバリア層３２ａ，３２ｂ，３２ｃのバンドギャップも、正孔供給側であるｐ-ＡｌＧａＮクラッド層２２側から低減させてある。設計では、障壁層の両端を除き、障壁層に隣接する井戸層のバンドギャプの大きい方をＥＷＬ［ｅＶ］とすると、該障壁層のバンドギャップＥＢ［ｅＶ］は、ＥＢ＜ＥＷＬ＋０．８とした。この様に障壁層のバンドギャップを井戸層のバンドギャップのリンクさせることは、非常に動き難い正孔にポテンシャル場を与えて好都合である。

【００１６】このようにして作製した多色発光素子は、各グループから発せられるほぼ６００ｎｍ、５３５ｎｍ、４７０ｎｍの３つのピーク波長を持ち、これらの発光光が互いに干渉することで、出力されるのは白色光となる。このような白色光源をランプに加工して発光出力を計測したところ、出力は２０ｍＷ（＠２０ｍＡ通電時）、駆動電圧は青色ＬＥＤと同じ３．６Ｖ（平均値）が得ることができた。

【００１７】図３は、同様にグループ毎にバンドギャップを異ならせた場合の例であって、２波長発光素子とした場合の発光層３のバンド構造を模式的に示している。発光層３は井戸層のバンドギャップを異ならせることで２つに区画した、第１グループ３ａ、第２グループ３ｂとからなっており、図２の例の場合と同様に全て無添加のＩｎＧａＮで構成している。図３の例でも、電子は均一に拡散していると考えて良く、発光波長のバランスは正孔の分布によってほぼ決定されると考えられる。ここでは、ｐ-ＡｌＧａＮクラッド層２２側、即ち正孔の注入側に約４７５ｎｍの青色を発する２層の井戸層３３ｂ及びバリア層３４ｂからなる第２グループ３ｂを配し、約５７５ｎｍの黄色を発する５層の井戸層３３ａ及びバリア層３４ａからなる第１グループ３ａをｎ－ＧａＮコンタクト層２１側に配した。これは、正孔密度が低下し視感度も低下することを勘案してである。また、正孔がより拡散し易くするためにバリア層３４ａ，３４ｂのバンドギャップもｐ-ＡｌＧａＮクラッド層２２側から低減させるようにした。

【００１８】このようにして作製した多色発光素子は、ほぼ５７５ｎｍ、４７５ｎｍの２つのピーク波長を持った白色光源であり、ランプに加工して発光出力を計測したところ、出力は２５ｍＷ（＠２０ｍＡ通電時）、駆動電圧は青色ＬＥＤと同じ３．６Ｖ（平均値）が得られた。

【００１９】上記の２種類の白色光源を比較すると、出力的には後者の２波長発光の方が高いが、平均演色評価数で比較すると前者の光源が、Ｒａ＝９２であるのに対し、後者はＲａ＝７７と低い結果であった。従って、平均演色評価数の高い光源用には発光波長に対応する井戸層の種類を増やす事が重要であると言える。

【００２０】本発明の多色発光素子において、発光出力が一定のレベル以上である条件を詳しく調べた結果を、図２を用いて説明する。井戸層にｐ-ＡｌＧａＮ側より番号（ｎ）を付け、そのバンドギャップＥＷ（ｎ）（便宜的に発光波長（λｐ［μｍ］）からＥＷ［ｅＶ］＝１．２３９８／λｐで定義する）と、同様にｐ-ＧａＮ側バリア層の端層から番号（ｍ）を付け、そのバンドギャップＥＢ（ｍ）（ＩｎＮ混晶比をＸとして、ＥＢ［ｅＶ］＝３．３９－２．５０Ｘ＋X^2で算出、Ｘは設定値）において、①ＥＢ（ｎ）及びＥＢ（ｎ＋１）＜ＥＷ（ｎ）、②ＥＷ（ｎ）及びＥＢ（ｍ）のそれぞれｎ、ｍの一次関数近似が負の勾配を持つこと、が発光出力が一定のレベル以上である条件であった。

【００２１】ここではサファイアＣ面基板を例示したが、この他に、サファイアＡ面（Ｒ面）、ＳｉＣ（６Ｈ、４Ｈ、３Ｃ）、ＧａＮ、ＡｌＮ、Ｓｉ、スピネル、ＺｎＯ，ＧａＡｓ，ＮＧＯなどを用いることができるが、発明の目的に対応するならばこのほかの材料を用いてもよい。なお、基板の面方位は特に限定されなく、更にジャスト基板でも良いしオフ角を付与した基板であっても良い。また、サファイア基板などに数μｍのＧａＮ系半導体をエピタキシャル成長してある基板を用いても良い。

【００２２】基板上に成長される半導体層として図１ではＧａＮ、ＩｎＧａＮ、ＡｌＧａＮが例示されているが、本目的を達成するためには$Al_yIn_xGa_{1-x-y}N$（０≦ｘ≦１、０≦ｙ≦１、０≦ｘ+ｙ≦１）で一般化されｘ、ｙの組成比で規定される適切な層構造を選ぶ事ができる。

【００２３】井戸層の配置に付いて好適な例をここでは述べたが、高ＩｎＮ混晶比のＩｎＧａＮの耐熱性が問題になる場合がある。これは、結晶成長装置に大きくは依存しているが、ｎ-ＧａＮコンタクト層２１を成長した後、７００℃に降温して$In_{0.8}Ga_{0.2}N$井戸層を成長してから、ｐ-ＧａＮコンタクト層２３を成長し終わるまで数時間必要である。この中の多くの部分は発光層の成長に費やされる。結晶成長装置によっては、この間に蒙る熱ダメージが問題になり、発光出力が上がらないことになる。

【００２４】この場合は、短波長側から製膜することで、高ＩｎＮ混晶比のＩｎＧａＮを最後に積む事で回避できる。この場合は電子を供給する側（ｎ型半導体層

側）に短波長を発光する井戸層を配した多波長発光素子が実現されることになる。即ち、図２に示した実施例の多波長発光素子の場合に、上記の熱ダメージの問題を重視するならば、電子を供給する側であるｎ－ＧａＮコンタクト層２１に隣接させて最も短波長である４７０ｎｍの青色発光をなす第３グループ３ｃの量子井戸部分を配置し、ｐ－ＡｌＧａＮクラッド層２２側に最も長波長である６００ｎｍの朱色発光をなす第１グループ３ａを配置すれば良い。図３に示す実施例の場合も、第１グループ３ａと第２グループ３ｂとの配置場所を入れ替えれば良い。

【００２５】以上説明した実施例では、井戸層の組成を主に異ならせることでバンドギャップを異ならせ、発光波長を異ならせる場合について例示したが、これ以外にも例えば、井戸層幅、ドーピング量又は種類、ピエゾ電界強度などのいずれか一種または二種以上を異ならせる方法も採用することができる。

【００２６】井戸層幅を異ならせた場合、量子効果による実効的なバンドギャップが変化し発光波長が変化する効果と、ピエゾ電界によるバンド構造の傾斜に起因して実効的なバンドギャップが変化する効果が存在する。井戸層幅を広くするとピエゾ電界の効果が大きくなり、発光波長は長波長にシフトするので、発光波長を異ならせることができる。例えば約４７５ｎｍの青色光と約５７５ｎｍの黄色光とを発するようにするには、井戸層の幅を２．５ｎｍ、７．５ｎｍにそれぞれ設定すれば良い。

【００２７】また故意に添加した不純物が形成する深い準位に関係した発光を積極的に利用することで、井戸層中に添加するドーピング量又は種類を調整し、発光波長を異ならせることができる。例えば、特定の井戸層中にＺｎを、或いはＺｎ及びＳｉを添加することで、発光波長の調整を行うことができる。

【００２８】ピエゾ電界強度は、井戸層に掛かる応力を層構造の設計で制御する事ができ、実効的なバンドギャップを異ならせることによって発光波長を異ならせることができる。例えば、井戸層を挟んでいる障壁層の組成を格子定数の小さくなる様に、具体的には障壁層にＡｌを半導体組成成分として添加すると井戸層に圧縮歪が加わり、やはり実効的なバンドギャップを変化させ、発光波長が長波長に変化する。この様に、発光層の中の障壁層、又はクラッド層の組成、更には下地層の厚み、基板などを調整し、応力を変化させることで、発光波長の調整を行うことができる。

【００２９】

【実施例１】本発明の多波長発光素子の一実施例である図１に示す断面構造の素子を、次のようにして作製した。５００μｍ厚のサファイアＣ面基板を使い、結晶成長装置は通常の常圧ＭＯＶＰＥ（有機金属気相エピタキシャル成長）装置を使った。ＭＯＶＰＥ装置内に該サファイア基板を装着し、水素リッチ気流中で１１００℃まで昇温した。所定時間保持してサーマルエッチングを行なった後、４５０℃まで降温し、低温成長ＧａＮバッファ層を約２０ｎｍ成長した。続いて１０００℃まで昇温し、１０００ｎｍの無添加ＧａＮを成長し、３０００ｎｍのｎ−ＧａＮ層（Ｓｉ添加）を成長した。７００℃に降温した後、最初の障壁層（ｍ＝６）$In_{0.05}Ga_{0.95}N$を１０ｎｍ成長し、３層の$In_{0.76}Ga_{0.24}N$（２．５ｎｍ厚）と２層の障壁層$In_{0.35}Ga_{0.65}N$（６ｎｍ厚）及び障壁層$In_{0.2}Ga_{0.8}N$（ｍ＝３、６ｎｍ厚）を成長し、更に、第２井戸層$In_{0.55}Ga_{0.45}N$（２．５ｎｍ厚）、第２障壁層$In_{0.1}Ga_{0.9}N$（６ｎｍ厚）、第１井戸層$In_{0.35}Ga_{0.75}N$（２．５ｎｍ厚）、第１障壁層$In_{0.05}Ga_{0.95}N$（１０ｎｍ厚）を成長し、発光層とした。尚、組成は前述の発光波長から算出したバンドギャップ値から、$Eg\,[eV]=3.39-2.50X+X^2$を使って概算した値を使った。発光層の成長終了後、再び１０００℃まで昇温しＭｇを添加した５０ｎｍの$Al_{0.2}Ga_{0.8}N$クラッド層を成長し、同じくＭｇを添加した１００ｎｍのＧａＮコンタクト層を更に成長した。結晶成長終了後、８５０℃まで温度が下がった段階でアンモニアガス、水素ガスを全て窒素ガス流に切り換え、そのまま室温近くまで冷却した。ＭＯＶＰＥ炉から基板を取り出し、通常のフォトリソグラフィ技術、電子ビーム蒸着技術、リアクティブイオンエッチング（ＲＩＥ）技術などを使ってエッチング加工、電極形成等を行い、最終的にＬＥＤチップに加工・分割した。

【００３０】得られたＬＥＤチップをエポキシ系樹脂を使ってＬＥＤランプに加工し、発光特性を測定評価した。発光波長は、ほぼ６００ｎｍ、５３５ｎｍ、４７０ｎｍの三つのピーク波長を持った白色光源であり、発光出力は２０ｍＷ（＠２０ｍＡ通電時）、駆動電圧は青色ＬＥＤと同じ３．６Ｖ（平均値）であった。従来の蛍光体を使った白色光源より２倍近く明るいランプとなった。平均演色評価数はＲａ＝９２であった。

【００３１】

【実施例２】実施例１と同様の方法にて、多色発光素子を作製した。発光層は、ｎ−ＧａＮ層（Ｓｉ添加）を成長後に７００℃に降温し、ｎ側の障壁層（ｍ＝８）$In_{0.05}Ga_{0.95}N$を１０ｎｍ成長し、５層の$In_{0.68}Ga_{0.32}N$（２．５ｎｍ厚）と４層の障壁層$In_{0.3}Ga_{0.7}N$（６ｎｍ厚）及び第３障壁層$In_{0.1}Ga_{0.9}N$（６ｎｍ厚）を成長し、更に、第２井戸層$In_{0.35}Ga_{0.65}N$（２．５ｎｍ厚）、第２障壁層$In_{0.1}Ga_{0.9}N$（６ｎｍ厚）、第１井戸層$In_{0.35}Ga_{0.75}N$（２．５ｎｍ厚）、第１障壁層$In_{0.05}Ga_{0.95}N$（１０ｎｍ厚）を成長した。

【００３２】得られたＬＥＤチップをエポキシ系樹脂を使ってＬＥＤランプに加工し、発光特性を測定評価した。発光スペクトルに、ほぼ５７５ｎｍ、４７０ｎｍの

２つのピークを持った白色光源となっており、発光出力は２５ｍＷ（＠２０ｍＡ通電時）、駆動電圧は青色ＬＥＤと同じ３．６Ｖ（平均値）であった。従来の蛍光体を使った白色光源より約２倍強明るいランプとなった。平均演色評価数はＲａ＝７７であった。

【００３３】

【発明の効果】以上説明した通りの本発明の多波長発光素子は、ＬＥＤ式の白色光源として好適に用いることができる。この場合従来方式に比べて、蛍光体を用いない直接電光変換方式であるのでエネルギー利用効率は良く、また発光層は見かけ上は一層であるので素子構造の複雑化等を伴うことはない。従って、駆動回路が単純化が可能で且つ高効率であり、しかも単一発光層故に劣化モードの違いに起因した色調の変化も無く、波長混合性にも優れる白色光源を実現できる。＊

＊【図面の簡単な説明】

【図１】本発明の多波長発光素子の断面図である。

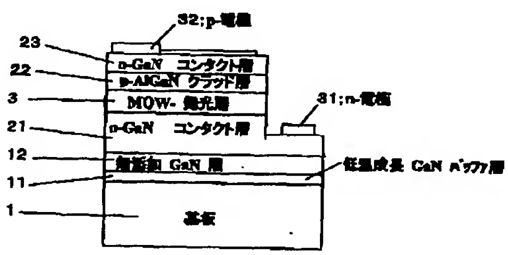
【図２】本発明にかかる３波長発光素子の発光層のバンド構造を示す模式図である。

【図３】本発明にかかる２波長発光素子の発光層のバンド構造を示す模式図である。

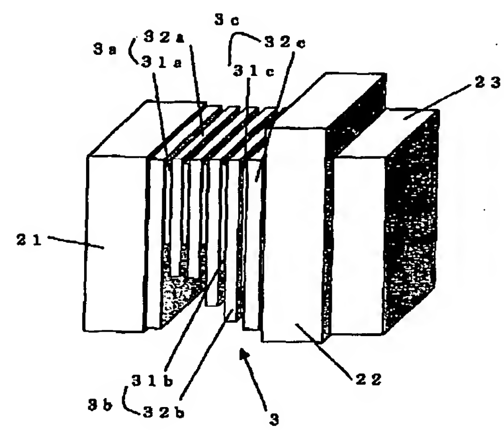
【符号の説明】

1　基板
２１　ｎ－ＧａＮコンタクト層
２２　ｐ－ＡｌＧａＮクラッド層
２３　Ｐ－ＧａＮコンタクト層
3　発光層
３１ａ，３１ｂ，３１ｃ　井戸層
３２ａ，３２ｂ，３２ｃ　バリア層

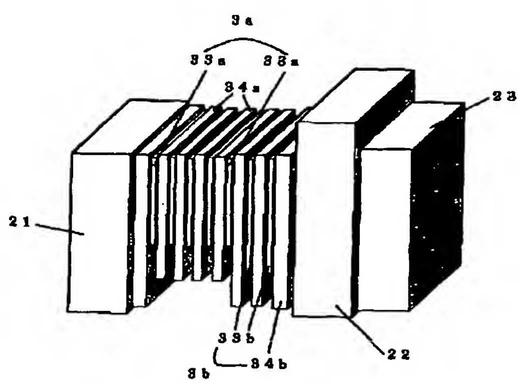
【図１】



【図２】



【図３】



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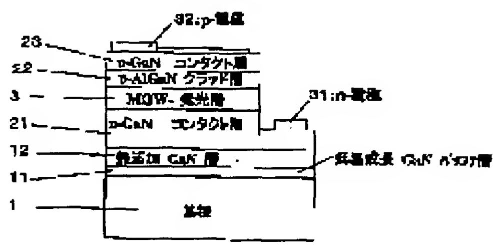
(54) MULTI-WAVELENGTH LIGHT EMITTING ELEMENT

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a light emitting element emitting light of a plurality of wavelengths from a single emission layer and emitting light of multiple colors, especially white color, by simply injecting a current into a set of p-type and n-type electrodes.
SOLUTION: The element structure comprises a sapphire C face substrate 1, a GaN buffer layer 11 grown under a low temperature, an undoped GaN layer 12, an Si doped n-GaN contact layer 21, a multiple quantum well MQW emission layer 3 having a plurality of well layers, an Mg doped p-AlGaN clad layer 22, and an Mg doped p-GaN contact layer 23. The emission layer 3 can emit light of a plurality of wavelengths by providing such a multilayer structure as the emitted light includes two or more peaks in the emission spectrum, e.g. a plurality of groups where the band gap of the well layers is differentiated.



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* NOTICES *

CLAIMS

[Claim(s)]

[Claim 1] The multi-wavelength light emitting device characterized by having the multilayer structure which emits the light which includes at least two or more peaks in an emission spectrum in a light emitting device equipped with a n-type-semiconductor layer, a p type semiconductor layer, and the luminous layer that consists of multilayer structure in a luminous layer.

[Claim 2] The multi-wavelength light emitting device according to claim 1 characterized by the bird clapper from the multiplex quantum well structure where a luminous layer has two or more well layers.

[Claim 3] The multi-wavelength light emitting device according to claim 2 characterized by having arranged at least two or more quantum well layers which changed luminescence wavelength by changing any one sort of a band gap, well layer thickness, the amount of doping or a kind, and the piezo field strength, or two sorts or more in multiplex quantum well structure.

[Claim 4] The multi-wavelength light emitting device according to claim 2 to which luminescence wavelength is characterized by having the multiplex quantum well structure of having at least one [at a time] a less than 520nm well layer and a well layer 520nm or more, respectively, in a luminous layer.

[Claim 5] The multi-wavelength light emitting device according to claim 4 which luminescence wavelength sets the group of A and a well layer 520nm or more to B for the group of a less than 520nm well layer, and is characterized by allotting the well layer belonging to Group A to the side which supplies an electron hole.

[Claim 6] The multi-wavelength light emitting device according to claim 4 which luminescence wavelength sets the group of A and a well layer 520nm or more to B for the group of a less than 520nm well layer, and is characterized by allotting the well layer belonging to Group A to the side which supplies an electron.

[Claim 7] The multi-wavelength light emitting device according to claim 2 to which it is characterized by the well layer and luminescence wavelength of less than 500nm having [luminescence wavelength / the well layer and luminescence wavelength of less than 550nm] the multiplex quantum well structure of having a well layer 550nm or more one or more, respectively, in a luminous layer by 500nm or more.

[Claim 8] The multi-wavelength light emitting device according to claim 7 to which luminescence wavelength is characterized by allotting Group B in the middle which can come and looks Group C like [the side which supplies / the group of a less than 500nm well layer / an electron for Group A to the side to which B and luminescence wavelength set the group of a well layer 550nm or more to C for the group of a less than 550nm well layer by 500nm or more, and A and luminescence wavelength supply an electron hole].

[Claim 9] The multi-wavelength light emitting device according to claim 7 to which luminescence wavelength is characterized by allotting Group B in the middle which can come and looks Group C like [the side which supplies / the group of a less than 500nm well layer / an electron hole for Group A to the side to which B and luminescence wavelength set the group of a well layer 550nm or more to C for the group of a less than 550nm well layer by 500nm or more, and A and luminescence wavelength supply an electron].

[Claim 10] The multi-wavelength light emitting device according to claim 4 or 7 characterized by constituting so that it may become small towards the side which supplies an electron from the side which supplies an electron hole for the band gap of a well layer.

[Claim 11] The multi-wavelength light emitting device according to claim 4 or 7 characterized by considering as $EB<EWL +0.8$ [electronu volt] when the larger one of the band gap of the well layer which adjoins a barrier layer is set to EWL [electronu volt] and the band gap of this barrier layer is set to EB [electronu volt].

[Claim 12] The multi-wavelength light emitting device according to claim 4 or 7 characterized by

thickening width of face of the barrier layer which adjoins the well layer which emits the light of short wavelength compared with the barrier layer which adjoins the well layer which emits the light of long wavelength.

[Translation done.]

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] this invention relates to compound semiconductor element, especially a light emitting device.

[0002]

[Description of the Prior Art] Light Emitting Diode which carries out white luminescence is developed and put in practical use in combination with the fluorescent substance which is excited by the blue glow emitted from blue Light Emitting Diode and this Light Emitting Diode, and emits yellow fluorescence. The white light source using such a Light Emitting Diode (solid-state light emitting device) is expected as the new light source for lighting of the next generation. Otherwise, this white light source is realized by the combination of ultraviolet Light Emitting Diode and the fluorescent substance which changes ultraviolet radiation into many wavelength, the method of combining visible Light Emitting Diode of two or more colors, such as blue, green, and red, further, etc.

[0003] However, it is thought that the method using ultraviolet Light Emitting Diode has the large energy loss by wavelength conversion, and a limitation is in energy use efficiency in order to change into the light of low energy the ultraviolet rays which poured in the carrier of a high energy and emitted light. This problem exists similarly, when using it combining blue Light Emitting Diode and a fluorescent substance. On the other hand, in order that the method of acquiring the white light by the complementary color relation using visible Light Emitting Diode of two or more colors may not have wavelength conversion, energy use efficiency has the advantage of excelling. However, it becomes the multipoint light source, and since the degradation modes in which mixture of light is bad and in which a drive circuit becomes complicated since driver voltages differ for every luminescence wavelength differ for every luminescence wavelength, it has many troubles of a color tone changing with time.

[0004]

[Problem(s) to be Solved by the Invention] In view of the above-mentioned trouble, this invention persons tried to develop the high multi-wavelength light emitting device of the energy use efficiency by which direct current to light transference is carried out which does not include the wavelength conversion process using the fluorescent substance etc., and completed this invention.

[0005] By the way, various Light Emitting Diodes which emit light in many wavelength from one chip have been devised and developed. However, the laminating of the most is carried out as a different luminous layer for every luminescence wavelength, and it has structure which allotted the n-type-semiconductor layer and the p type semiconductor layer to the both sides of each luminous layer. Therefore, at least one external drawing electrode is needed for each luminous layer, and problems, such as change of the color tone by the difference between the complexity of a drive circuit and degradation mode, are not solved at all.

[0006] Unlike the above-mentioned conventional concept, this invention emits the light of two or more wavelength from a single luminous layer, and aims at offering the light emitting device based on the new concept which carries out multicolor luminescence only by moreover injecting current into p type and n type electrode of a lot. There is also no change of the color tone resulting from the difference between a single luminous layer, therefore degradation mode, it excels also in wavelength miscibility, and the white light source with which the drive circuit was also simplified and which is easy to treat is offered.

[0007]

[Means for Solving the Problem] In the conventional white light source, in order to solve the combination of the ** ultraviolet rays Light Emitting Diode or blue Light Emitting Diode, and a fluorescent substance, the combination of visible Light Emitting Diode of ** two or more colors, and the above-mentioned trouble of method ** using the multicolor luminescence chip of ** former, the new

element structure where multicolor luminescence was obtained from a single luminous layer was developed. That is, the multi-wavelength light emitting device of this invention is characterized by having the multilayer structure which emits the light which includes at least two or more peaks in an emission spectrum in a luminous layer in a light emitting device equipped with a n-type-semiconductor layer, a p type semiconductor layer, and the luminous layer that consists of multilayer structure.
[0008] The above-mentioned luminous layer has multiplex quantum well structure to a desirable bird clapper, and many wavelength-ization can be attained by arranging at least two or more quantum well layers which changed luminescence wavelength by changing any one sort of a band gap, well layer thickness, the amount of doping or a kind, and the piezo field strength, or two sorts or more in this case in multiplex quantum well structure.
[0009]
[Function] The multiplex quantum well structure generally used as a luminous layer in a light emitting device is carrying out structure which allotted two or more well layers which have the usually same properties (band gap etc.) in order to gather luminous efficiency. namely, a barrier layer (Barrier layer) / well layer (Well layer) / barrier layer / well layer / .. /-- a barrier layer -- in a multiplex quantum well layer, although a well layer is the same structure (composition, a band gap, well width of face) and a barrier layer may also apply a modulation about width of face, composition (band gap) is the same in many cases except for ends
[0010] On the other hand, it is making into the feature for the element structure which this invention persons developed to modulate composition (band gap) and width of face of the well layer and/or barrier layer which form the multiplex quantum well structure in one luminous layer, and efficient multicolor luminescence, especially white luminescence are obtained from a single luminous layer. That is, the light emitting device which enables it to obtain luminescence of different wavelength for every pair, has it by making two or more sorts of pairs of the well layer and barrier layer from which a property differs mutually intermingled in the layer recognized as one luminous layer in the usual light-emitting-device structure, and has at least two or more luminescence peaks in an emission spectrum is constituted. Since it is the direct current-to-light-transference method which does not use a fluorescent substance according to this composition, energy use efficiency is good, and since a luminous layer is a monostromatic seemingly, it is not accompanied by complication of element structure etc.
[0011]
[The mode of implementation of invention] Based on a drawing, it explains per embodiment of this invention below. Drawing 1 shows one example of the compound semiconductor light emitting device of this invention. The luminous layer 3 of multiplex quantum well structure (MQW) which has from the bottom the Cth page substrate 1 of sapphire, the GaN buffer layer 11 by which low-temperature growth was carried out, the additive-free GaN layer 12, the n-GaN contact layer 21 of Si addition, and two or more well layers, the p-AlGaN clad layer 22 of Mg addition, It consists of a p-GaN contact layer 23 of Mg addition, and the n electrode 31 is formed in the outcrop of the n-GaN contact layer 21, and the p electrode 32 is formed in the front face of the p-GaN contact layer 23, respectively. In this invention, the feature is made into multilayer structure to which the light emitted from the above-mentioned luminous layer 3 includes at least two or more peaks in an emission spectrum. In addition, with the peak said here, when two broadcloth peaks lap including not only a steep peak but a broadcloth peak and one peak is formed seemingly, it includes.
[0012] Let a luminous layer 3 be the multilayer structure which includes at least two or more peaks in an emission spectrum as above-mentioned. This multilayer structure is typically made into multiplex quantum well structure. This multiplex quantum well structure is the structure where make a well layer and a barrier layer into one pair, and two or more steps of such pairs are accumulated. And it classifies according to the number of the peak light which wants to generate the pair by which accumulation was carried out [aforementioned], namely, if it is a three-wave light emitting device, grouping will be carried out to three, and it is made to generate the light of two or more luminescence wavelength by changing any parameters [one sort of] of a band gap, well layer thickness, the amount of doping or a kind, and the piezo field strength, or two sorts or more for every group of the in this invention.
[0013] Drawing 2 is an example at the time of changing a band gap for every partition among the above-mentioned parameters, and is drawing having shown typically the band structure of the luminous layer 3 at the time of considering as a three-wave light emitting device. The luminous layer 3 consists of 1st group 3a divided to three, 2nd group 3b, and 3rd group 3c by changing the band gap of a well layer, and constitutes these all from additive-free InGaN. 1st group 3a which consists of well three-layer layer 31a and barrier layer 32a in the meantime which emit about 600nm vermilion color from the n-GaN contact layer 21 side in detail, 3rd group 3c which consists of well one-layer layer 31c and adjoining barrier layer

32c which emit 2nd group 3b which consists of well one-layer layer 31b and adjoining barrier layer 32b which emit about 535nm green, and about 470nm blue is arranged.
[0014] In the case of this material system, the average free process of the electron hole poured in into the barrier layer is said to be dozens of nm, and it becomes a technical problem although it should be made what layer structure in order to obtain multicolor luminescence which was made to pour in and diffuse an electron hole in a multiplex quantum well layer efficiently [how], or maintained balance. In the example of drawing 2 , you may think that the electron is diffused uniformly and the balance of luminescence wavelength is mostly determined by the distribution of an electron hole. Therefore, although 3rd group 3c which makes blue luminescence was allotted to the p-AlGaN clad layer 22 side which is the side which supplies an electron hole, since the density of an electron hole was also high, well layer 31c was taken as the monolayer. Although 2nd group 3b which makes green luminescence to the mid-position is allotted, and hole density falls a little, since green visibility is high, the monolayer of well layer 31b is next, enough also as this. Although the 1st group which makes vermilion color luminescence was finally allotted to the n-GaN contact layer 21 side, since it falls and visibility also falls, three layers well layer 31a is put in, and hole density constitutes it.
[0015] Moreover, in order to make an electron hole easier to diffuse, the band gap of the barrier layers 32a, 32b, and 32c is also reduced from the p-AlGaN clad layer 22 side which is an electron hole supply side. In the design, when the larger one of band GYAPU of the well layer which adjoins a barrier layer was set to EWL [electronu volt] except for the ends of a barrier layer, the band gap EB of this barrier layer [electronu volt] was taken as EB<EWL +0.8. Thus, it gives [the electron hole which is very hard to move] a potential field and is convenient that the band gap of a well layer makes the band gap of a barrier layer link.
[0016] Thus, it is that the produced multicolor light emitting device has three peak wavelengths, about 600nm, 535nm, and 470nm, emitted from each group, and such luminescence light interferes mutually, and being outputted becomes the white light. When such the white light source was processed into the lamp and the radiant power output was measured, 3.6V (average) as blue Light Emitting Diode with same 20mW (at the time of @20mA energization) and driver voltage were able to obtain the output.
[0017] Drawing 3 is an example at the time of changing a band gap for every group similarly, and shows typically the band structure of the luminous layer 3 at the time of considering as a two-wave light emitting device. The luminous layer 3 consists of 1st group 3a divided to two, and 2nd group 3b by changing the band gap of a well layer, and consists of additive-free InGaN(s) altogether like the case of the example of drawing 2 . Also in the example of drawing 3 , you may think that the electron is diffused uniformly, and it is thought that the balance of luminescence wavelength is mostly determined by the distribution of an electron hole. Here, 2nd group 3b which is from two-layer well layer 33b and barrier layer 34b which emit about 475nm blue on the p-AlGaN clad layer 22, i.e., pouring of electron hole, side was allotted, and 1st group 3a which consists of well five-layer layer 33a and barrier layer 34a which emit about 575nm yellow was allotted to the n-GaN contact layer 21 side. this takes into consideration that hole density falls and visibility also falls, and comes out Moreover, in order to make an electron hole easier to diffuse, it was made to also reduce the band gap of the barrier layers 34a and 34b from the p-AlGaN clad layer 22 side.
[0018] Thus, the produced multicolor light emitting device was the white light source with two peak wavelengths, about 575nm and 475nm, and when it was processed into the lamp and the radiant power output was measured, 3.6V (average) as blue Light Emitting Diode with 25mW (at the time of @20mA energization) and driver voltage same [an output] were obtained.
[0019] Although the latter two-wave luminescence was higher in output when two kinds of above-mentioned white light sources were compared, when the general color rendering index compared, the latter was Ra=77 and as a result of the low to the former light source being Ra=92. Therefore, it can be told to the high light sources of a general color rendering index that it is important to increase the kind of well layer corresponding to luminescence wavelength.
[0020] In the multicolor light emitting device of this invention, a radiant power output explains the result which investigated in detail the conditions which are more than fixed level using drawing 2 . A well layer is numbered from a p-AlGaN side (n). (It defines by EW[electronu volt] =1.2398/lambdap from luminescence wavelength (lambdap [mum]) for convenience), [the band gap EW (n) and] Calculation and X are set to set point) by EB[electronu-volt] =3.39-2.50 X+X2 by setting an InN mixed-crystal ratio to X. the same -- **** of a p-GaN side barrier layer to a number (m) -- attaching -- band-gap EB (m) (-- ** Having [linear-function approximation of n and m]-, respectively-negative inclination of EB (n) and EB(n+1) <EW(n) **EW(n) and EB (m) **s were the conditions which are more than level with a fixed radiant power output.

[0021] Although the Cth page substrate of sapphire was illustrated here, in addition although the Ath page (Rth page) of sapphire, SiC (6H, 4H, 3C), GaN, AlN and Si, a spinel, ZnO, GaAs, NGO, etc. can be used, you may use other material, if it corresponds to the purpose of invention. In addition, especially the field direction of a substrate may not be limited, and a substrate is sufficient as it further just, and it may be the substrate which gave the OFF angle. Moreover, you may use for silicon on sapphire etc. the substrate which has grown the several micrometers GaN system semiconductor epitaxially.
[0022] Although GaN, InGaN, and AlGaN are illustrated by drawing 1 as a semiconductor layer which grows on a substrate, in order to attain this purpose, the suitable layer structure which is generalized by AlyInxGa1-x-yN (0<=x<=1, 0<=y<=1, 0 <=x+y<=1), and is specified by the composition ratio of x and y can be chosen.
[0023] Although it is attached to arrangement of a well layer and a suitable example is described here, the thermal resistance of InGaN of a high InN mixed-crystal ratio may become a problem. Although it is greatly dependent on crystal-growth equipment, this is required for several hours after growing up the n-GaN contact layer 21, lowering the temperature at 700 degrees C and growing up an In0.8Ga0.2N well layer until it finishes growing up the p-GaN contact layer 23. Many portions in this are spent on growth of a luminous layer. The heat damage worn in the meantime depending on crystal-growth equipment becomes a problem, and a radiant power output will be improved.
[0024] In this case, it is producing a film from a short wavelength side, and can avoid by stacking InGaN of a high InN mixed-crystal ratio at the end. In this case, the multi-wavelength light emitting device which allotted the well layer which emits light in short wavelength to the side (n-type-semiconductor layer side) which supplies an electron will be realized. Namely, what is necessary is to arrange the quantum well portion of 3rd group 3c which is made to adjoin the n-GaN contact layer 21 which will be the side which supplies an electron if the problem of the above-mentioned heat damage is thought as important in the case of the multi-wavelength light emitting device of the example shown in drawing 2 , and makes 470nm blue luminescence which is short wavelength most, and just to arrange 1st group 3a which makes 600nm vermilion color luminescence which is long wavelength most to the p-AlGaN clad layer 22 side. Also in the example shown in drawing 3 , the arrangement place of 1st group 3a and 2nd group 3b should just be replaced.
[0025] Although illustrated in the example explained above about the case where change a band gap by mainly changing composition of a well layer, and luminescence wavelength is changed, the method of changing any one sort, such as well layer thickness, the amount of doping or a kind, and piezo field strength, or two sorts or more besides this is also employable.
[0026] When well layer thickness is changed, the effect that the efficiency-band gap by the quantum effect changes and luminescence wavelength changes, and the effect that originate in the inclination of the band structure by piezo electric field, and an efficiency-band gap changes exist. Since the effect of piezo electric field will become large and luminescence wavelength will be shifted to long wavelength if well layer thickness is made large, luminescence wavelength can be changed. For example, what is necessary is just to set the width of face of a well layer as 2.5nm and 7.5nm, respectively, in order to emit about 475nm blue glow and about 575nm yellow light.
[0027] Moreover, by using positively luminescence related to the deep level which the impurity added intentionally forms, the amount of doping or kind added in a well layer can be adjusted, and luminescence wavelength can be changed. for example, the inside of a specific well layer -- Zn -- or luminescence wavelength can be adjusted by adding Zn and Si
[0028] Piezo field strength can control the stress concerning a well layer by the design of a layer structure, and can change luminescence wavelength by changing an efficiency-band gap. For example, if aluminum is specifically added as a semiconductor composition component to a barrier layer so that it may become small [a lattice constant] about composition of the barrier layer whose well layer is pinched, a compressive strain will join a well layer, an efficiency--too band gap is changed, and luminescence wavelength changes to long wavelength. Thus, the thickness of a ground layer, a substrate, etc. can be adjusted further and luminescence wavelength can be adjusted by composition of the barrier layer in a luminous layer, or a clad layer, and changing stress.
[0029]
[Example 1] The element of the cross-section structure shown in drawing 1 which is one example of the multi-wavelength light emitting device of this invention was produced as follows. Using the Cth page substrate of sapphire of 500-micrometer **, crystal-growth equipment used usual ordinary-pressure MOVPE (organic-metal vapor phase epitaxial growth) equipment. It equipped with this silicon on sapphire in MOVPE equipment, and the temperature up was carried out to 1100 degrees C in the hydrogen rich air current. After carrying out predetermined-time maintenance and performing thermal

etching, the temperature was lowered to 450 degrees C and about 20nm grew the low-temperature growth GaN buffer layer. then -- up to 1000 degrees C -- a temperature up -- carrying out -- additive-free [1000nm] -- GaN was grown up and the 3000nm n-GaN layer (Si addition) was grown up After lowering the temperature at 700 degrees C, 10nm grows the first barrier layer (m= 6) In0.05Ga0.95N. In0.76Ga0.24N (2.5nm **) of three layers, two-layer barrier layer In0.35Ga0.65N (6nm **), and barrier layer In0.2Ga0.8N (m=3 or 6nm **) are grown up. Furthermore, it grew up and 2nd well layer In0.55Ga0.45N (2.5nm **), 2nd barrier layer In0.1Ga0.9N (6nm **), 1st well layer In0.35Ga0.75N (2.5nm **), and 1st barrier layer In0.05Ga0.95N (10nm **) were made into the luminous layer. In addition, composition used the value estimated using Eg[electronu-volt] =3.39-2.50 X+X2 from the band-gap value computed from the above-mentioned luminescence wavelength. The 50nm aluminum0.2Ga0.8N clad layer which carried out the temperature up to 1000 degrees C again, and added Mg after the growth end of a luminous layer was grown up, and the 100nm GaN contact layer which similarly added Mg was grown up further. After the crystal-growth end, to 850 degrees C, all of ammonia gas and hydrogen gas were switched in the style of nitrogen gas, and it cooled to near the room temperature as it is in the stage in which temperature fell. The substrate was taken out from the MOVPE furnace, etching processing, electrode formation, etc. were performed using the usual photolithography technology, electron-beam-evaporation technology, reactive-ion-etching (RIE) technology, etc., and, finally it processed and divided at the Light Emitting Diode chip.

[0030] The obtained Light Emitting Diode chip was processed into the Light Emitting Diode lamp using the epoxy system resin, and measurement evaluation of the luminescence property was carried out. Luminescence wavelength was the white light source with three peak wavelengths, about 600nm, 535nm, and 470nm, and the radiant power output was 3.6V (average) as blue Light Emitting Diode with same 20mW (at the time of @20mA energization) and driver voltage. the white light source using the conventional fluorescent substance -- near double precision -- it became a bright lamp The general color rendering index was Ra=92.

[0031]

[Example 2] The multicolor light emitting device was produced by the same method as an example 1. A luminous layer lowers a n-GaN layer (Si addition) at 700 degrees C, after growing up. 10nm grows barrier layer (m= 8) In0.05Ga0.95N by the side of n. Five-layer In0.68Ga0.32N (2.5nm **) and four layers reach barrier layer In0.3Ga0.7N (6nm **), and 3rd barrier layer In0.1Ga0.9N (6nm **) is grown up. Furthermore, 2nd well layer In0.35Ga0.65N (2.5nm **), 2nd barrier layer In0.1Ga0.9N (6nm **), 1st well layer In0.35Ga0.75N (2.5nm **), and 1st barrier layer In0.05Ga0.95N (10nm **) were grown up.

[0032] The obtained Light Emitting Diode chip was processed into the Light Emitting Diode lamp using the epoxy system resin, and measurement evaluation of the luminescence property was carried out. It had become the white light source which had two peaks, about 575nm and 470nm, in the emission spectrum, and the radiant power output was 3.6V (average) as blue Light Emitting Diode with same 25mW (at the time of @20mA energization) and driver voltage. It became a lamp brighter about 2 or so times than the white light source using the conventional fluorescent substance. The general color rendering index was Ra=77.

[0033]

[Effect of the Invention] The multi-wavelength light emitting device of this invention as explained above can be suitably used as the white light source of a Light Emitting Diode formula. In this case, since it is the direct current-to-light-transference method which does not use a fluorescent substance compared with the conventional method, energy use efficiency is good, and since a luminous layer is a monostromatic seemingly, it is not accompanied by complication of element structure etc. Therefore, a drive circuit can be simplified, and it is efficient, there is also no change of the color tone which moreover originated in the difference between a single luminous layer, therefore degradation mode, and the white light source which is excellent also in wavelength miscibility can be realized.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[Drawing 1] It is the cross section of the multi-wavelength light emitting device of this invention.
[Drawing 2] It is the ** type view showing the band structure of the luminous layer of the three-wave light emitting device concerning this invention.
[Drawing 3] It is the ** type view showing the band structure of the luminous layer of the two-wave light emitting device concerning this invention.
[Description of Notations]
1 Substrate
21 N-GaN Contact Layer
22 P-AlGaN Clad Layer
23 P-GaN Contact Layer
3 Luminous Layer
31a, 31b, 31c Well layer
32a, 32b, 32c Barrier layer

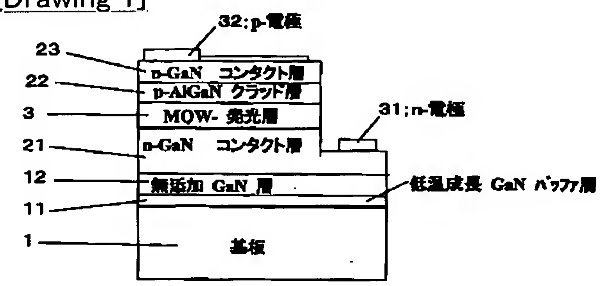
* NOTICES *

Japan Patent Office is not responsible for any damages caused by the use of this translation.

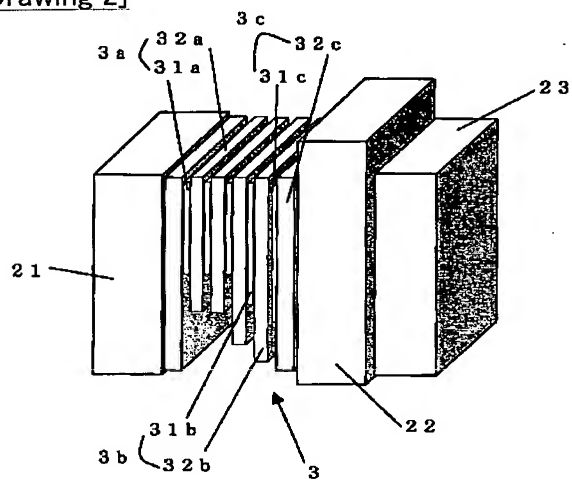
1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DRAWINGS

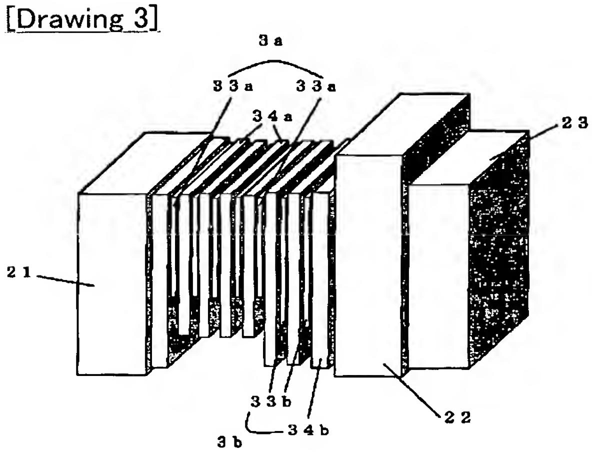
[Drawing 1]



[Drawing 2]



[Drawing 3]



[Translation done.]